

SDMS Document ID



2118885

2118885

EPA NO. 1590002

FILE NO. P1-22

Attachment A

(request dated 28, 2000)

HECLA MINING COMPANY
APEX PROJECT
OPERATIONS PROCEDURE MANUAL

DECEMBER 1989

NAME : _____

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the No. 2 and No. 1 strippers. The strip solution leaving the No. 1 stripper has removed essentially all of the copper from the organic and has become much more concentrated in copper. It is now called the "loaded strip" solution and goes to the loaded strip surge tank (TK-403). This tank is equipped with a jack-leg outlet that prevents the tank from being emptied. This allows any small droplets of organic carried from the strip circuit time to separate from the aqueous. To further remove organic from this stream before the electrowinning steps, it must pass through a sand filter before entering the electrolyte storage tank (TKH-706).

7.1.2 Circuit Operating Controls

Solution Preparation

The solution pH must be between 1.7 and 1.9 for proper operation of the extraction circuit. A pH higher than 1.9 may result in iron precipitation and emulsion formation while the copper will not extract efficiently if the pH of the solution is below 1.7.

The solution must be clarified to no more than 5 NTU. The solution clarity is tested with a bench turbidity meter. A procedure for turbidity testing is included in Appendix A.

It is important to the overall operation of the mill to realize that the sx throughput must be consistent with the solution balance of the mill. Failure to process solution fast enough will result in the surge tanks filling up and forcing the rest of the plant to shut down. Processing solutions too fast may result in too much solution in the gallium and/or germanium sx circuits. It is also important not to empty the surge tanks completely since that would possibly cause a loss of feed to the sx circuit, could stir up any solids settled on the bottom of the tank, and create severe disruption of the operation.

Extraction Circuit

It is very important in the extraction circuit to make sure that the proper organic flowrate is maintained for the given sx feedrate and copper assay. Too little organic flow will result in high copper raffinate losses since the organic can only pick up a given amount of copper. Too much organic flow means that there is more chemical available to load copper than there is copper, and in the absence of copper, it will load unwanted impurities. The proper organic to sx feed ratio is established through the shift foreman by the metallurgical department.

The sx feed and barren organic streams are equipped with flow meters and flow control valves. It is expected that the instrumentation on the sx feed and organic flow controllers will work together to change the organic flowrate to match any changes in the sx feed flowrate; however, the necessary ratio of organic flow to the sx feed flow will fluctuate depending on the copper concentration of the sx feed sample and the loading capacity of the organic. Samples of the organic in the circuit will be monitored periodically by the metallurgical department to determine its chemical content and its loading capacity. Each shift a sample of the loaded organic will be taken and analyzed to insure that it is picking up the expected amount of copper.

The raffinate (leach solution with the copper removed) is analyzed every three hours to insure that all copper is being extracted. An automatic sampler will take a 24 hr. sample to be used for metallurgical accounting purposes. Should a high raffinate (greater than .01 g cu/l) be obtained, an increase in organic flowrate may be required to correct the situation. Other factors that might give a high raffinate include: a pH below 1.8 in the sx feed of extractors, a depletion of LIX 84 in the circuit or excessive carryover of strip solution entrained in the barren organic.

The rate that the organic and aqueous mixture separates back into separate liquids is an important parameter to monitor in the copper sx extractors. If the liquids don't separate rapidly enough the mixed emulsion will eventually overflow the end of the settler, and the circuit must be shut down. When a sample of the mixture in a mixer is dipped from the tank the time is measured until the two phases separate completely. The time for complete organic and aqueous phase separation is called the "break time". Each mixer in the circuit is monitored at least twice per shift. Any drastic changes in mixer break time will inevitably result in circuit problems within a short period of time. Some of the circumstances that might result in a longer than normal break time include: loss of mixer organic to aqueous ratios, solids in the sx feed (or stirred up from the bottom of any settler) or cold solutions.

The same sample dipped from the mixer is also used to determine the organic to aqueous phase ratio in the mixers. For example, if there is 400 ml of organic and 200 ml of aqueous in the beaker after the two phases separate completely, the O/A (organic to aqueous phase ratio) is 2. Each extractor mixer has an internal recycle from the organic back into the mixer so that there is actually more

organic going into each mixer than is entering from the barren organic tank and advancing from one stage to the next. This recycle returns a portion of the organic that has separated out in the settler back into the mixer so that the mixer sees a larger volume of organic than is actually advancing between stages in the circuit. The internal recycling of organic is important to the operation of the circuit since it helps control the "continuous phase" and break time in the mixer.

The copper sx extraction circuit is designed to operate in either an organic continuous or an aqueous continuous mode. A mixture of oil and water can either be a mixture of oil in the water or water in the oil. If the aqueous is dispersed as small droplets in the organic upon mixing, the phase is said to be organic continuous. Likewise, if the organic is dispersed as droplets in the aqueous phase, the mixture is said to be aqueous continuous.

It is sometimes difficult to determine which is the continuous phase in an oil/water mixture. Usually, the continuous phase will be the one that is present in the greatest volume. If a mixture separates out and there is twice as much organic as there is aqueous volume, the mixture was probably an organic continuous mixture.

Another method of determining which is the continuous phase is by measuring the electrical conductivity of the mixture. If battery is attached to a light bulb and two non touching contact points and the contact points are lowered into a mixture of oil and water, electricity will flow between the contact points and light the bulb if the mixture is aqueous continuous. No electricity will flow between the contact points if the mixture is organic continuous since the oil will not conduct electricity and the droplets of aqueous (that will) are insulated from each other by the continuous organic phase.

A third method of determining which is the continuous phase is by watching the mixture separate. Usually, the continuous phase is the one which settles out as a distinct, clear phase first. Sometimes, however, it is difficult to determine which phase separates out first since both will develop almost simultaneously.

It is important to understand which phase is continuous for a couple of reasons: 1) the time that it takes for the mixture to separate usually is different for an organic continuous system than for the same mixture as an aqueous system, and 2) the amount of carryover in the organic (or aqueous) depends on which phase is continuous. In an organic continuous system, there is very little organic

carried over in the aqueous, but there is aqueous carried over with the organic (as fine droplets that haven't completely settled out of the organic). In an aqueous continuous system the aqueous phase will contain small droplets of organic, but there will be very little aqueous carried over with the organic.

The relative amounts of organic and aqueous in the mixers (O/A ratio) is important information to have since it should show any problems with plugged or restricted recycles before they become major problems and cause the continuous phase to change.

When possible, it is a good idea to operate the No. 1 Extractor aqueous continuous to minimize the amount of aqueous that gets carried over with the organic, and to operate the No. 4 Extractor organic continuous to minimize the amount of organic that gets carried out with the raffinate. Organic-loss to the raffinate results in costly organic loss and possible cross contamination with organics in the gallium and germanium sx circuits.

Wash and Strip Section

The organic flowrate through the wash and strip sections of the sx circuit are controlled by the flowrate of the barren organic, and whatever organic is fed into the extraction circuit must be processed through the wash and strip sections of the circuit.

The wash and strip solution flowrates are adjusted depending on the organic flowrate. These flow streams have rotometers to adjust and control these flows. The operator will set these flows as directed through the shift foreman by the metallurgical department.

In the wash and strip stages of the circuit, the recycle lines are aqueous recycles (either wash solution or strip solution) since the advancing aqueous flow is so small compared to the organic flow. In order to maintain a reasonable separation (break time) in the mixers, it is necessary to increase the aqueous liquid volume in the mixers and this is the reason for the aqueous recycles.

It is necessary for the operator to monitor the free acid content of the spent electrolyte (strip solution) in the spent electrolyte storage tank to make sure that the acid strength is 200-220 g H_2SO_4 /liter of solution. If the acid strength gets too low, the copper will not be completely stripped from the organic.

The loaded strip solution (preg. electrolyte) and spent electrolyte are sampled along with the copper sx feed and raffinate every three hours to monitor the sx and electrowinning operation. Samples of the loaded organic and stripped organic are taken once per shift (just before the end of the shift) and analyzed by the laboratory to assist the operator and other personnel control the operation and insure that the circuit is performing satisfactorily.

The loaded strip solution is filtered through two sand filters to remove as much organic as possible before the electrowinning part of the circuit. The pressure gauges on the sand filters are the primary indicators of the condition of the filtering media inside. When the backpressure on the filter increases to near the maximum output pressure of the pump feeding the filters, the filters may be plugged and must be backwashed or the filter media replaced. During the backwash of the sand, water is fed into the base of the sand filter at a rate high enough to "fluff" up the sand load in the filter and wash the entrapped organic and solids out the top. This backwashed material is sent to tails for disposal.

After filtering, the loaded strip solution (preg. electrolyte) is ready for the electrowinning operation.

7.1.3 Sampling Requirements

The following table summarizes the routine daily sampling that is required for monitoring the copper solvent extraction:

<u>Stream Sampled</u>	<u>Sample Point</u>	<u>Frequency</u>
copper sx feed	polished surge tk.	every three hrs.
copper sx feed	polished surge tk.	24 hr. composite
copper sx raffinate	No. 4 ext. aq. disch.	every three hrs.
copper sx raffinate	No. 4 ext. aq. disch.	24 hr. composite
copper loaded org.	No. 1 ext. org. disch.	1 hr. before end of shift
copper stripped organic	No. 3 stripper org. discharge	1 hr. before end of shift
copper spent elect.	spent elect. tank	every three hrs.
copper loaded strip (preg. electrolyte)	No. 1 stripper aqueous discharge	every three hrs.

acid is used in the spent electrolyte to restore its acid strength. The organic in the circuit consists of a kerosene type oil with 10% LIX 84 dissolved in it. All solutions within the circuit are acid to some degree and proper clothing and cleanliness are required to protect the skin from dermatitis and possibly chemical burns. Operators should be especially familiar with the special handling requirements for these chemicals and their individual hazards. Appropriate protective clothing and goggles must be worn.

In accordance with plant safety rules, a respirator should be carried with the operator at all times along with the appropriate cartridges. In the sx circuit the operator may be exposed to ammonia gas fumes, sulfuric acid fumes or vapors and organic vapors.

It is further emphasized that any part of the sx circuit area is off limits to smoking and that any violation of that rule will result in employee dismissal (ie, employee de hiring, alternate career enhancement, firing, etc.).

Inevitably in handling the organics in the circuit, walkways and boots will get coated with the organic and the potential for slipping increases. It is important to keep the area as clean as possible to help minimize the slipping hazards.

The organic in the circuit will eventually attack the rubber boots and as soon as a hole develops, the boots should be replaced. Don't wait until stepping into a pool of acid solution and getting a bootful of solution before determining that the boots should be replaced.

Walking or standing on the mixer or settler units should be avoided. The equipment is not designed to support much weight and a serious slipping hazard exists.

General safety precautions should be adhered to. There is a considerable amount of equipment in the copper sx circuit and safety cannot be taken lightly.

8.0 Gallium Solvent Extraction

After the copper has been removed from the leach solution, the gallium (along with zinc and some iron) are removed from the copper raffinate (or gallium sx feed) by solvent extraction (sx), and stripped into an aqueous solution from which the gallium can be selectively removed.

8.1 Process Description

Copper sx raffinate solution is clarified and contacted four times with an organic (kerosene type) that contains 10 vol.

% DEHPA (see glossary) and 5 vol. % TBP (see glossary) which is able to extract the zinc and gallium. The "loaded" organic is washed with a mild acid solution and the values are removed from the organic after contacting the organic four times with a strong acid solution. The acid solution (preg or loaded strip solution) is then treated in the gallium precipitation and refining sections to produce a final gallium metal product.

The gallium sx circuit includes a solution preparation section, four stages (mixer-settlers) of extraction, one wash stage on the loaded organic, four stages of stripping and one stage of organic scrubbing.

8.1.1 Material Flow

A copy of the gallium solvent extraction circuit flow diagram is included as figure 8.1.1.

Solution Preparation

Copper raffinate from the copper solvent scavenger tank (S-301-58) is pumped to the reactor tank (TK-501-1) of the gallium sx circuit. The reactor tank is an agitated tank into which ammonia gas is added. The amount of ammonia gas added to the tank is controlled by a pH probe that controls the ammonia addition control valve. The reactor tank is always full and it overflows into the surge tank (TK-501-3) that feeds a filter press (F-501-5).

The filter press is used to remove any suspended solids in the solution before solvent extraction. Solvent extraction circuits do not tolerate suspended solids very well. If essentially all solids are not removed from the solutions, they will mix with the organic and aqueous solutions in the mixers and will prevent the two liquids from separating in the settler units, usually collecting at the boundary (interface) between the organic and aqueous layers to form what is known as "grungies", crud or stable emulsions.

The filter press is built so that solutions must pass through a filter paper or cloth before leaving the press. Solids are trapped in the filter and removed later. As solids build up inside the filter, it becomes harder for the solutions to pass through the filter paper or cloth and the filter press will build a back pressure. The pressure gauge on the filter press will build a higher pressure until no more solution can pass through the filter and the filter press must be disassembled and cleaned.

For more difficult to filter materials it is possible to use a filter aid (easily filterable and porous material) to improve the filtration through either a precoat or a body feed method of addition. A discussion of those methods of filtering is given in section 7.1.1 of the copper sx circuit section of this manual.

After the solution is clarified through the filter press, it discharges into a feed tank (TK-501-6) which provides surge capacity. The pump from this tank pumps through a control valve that senses and regulates the flow into the extraction circuit based either on the level of solution in the feed tank or the operator manual set point. A continuous uniform flow of sx feed solution is essential to the smooth operation of this circuit since any major fluctuations will start a surge through all of the extractors and strip cells. Any changes in feed rate are made slowly.

Extraction

Gallium and zinc are transferred from the aqueous feed solution by mixing it with an organic (kerosene-type) containing DEHPA and TBP. It is essentially the DEHPA that actually attaches to the zinc and gallium to do the extraction. The TBP is required in the organic to keep the DEHPA soluble in the organic.

Four extraction stages are used because the extraction of the zinc and gallium are not 100 % complete in just one contact with the organic. The flows through the extraction are counter-current which means that the liquids advance in different directions. The sx feed aqueous enters into the No. 1 extractor and advances through Nos. 2 and 3 and exits the extraction circuit from No. 4. The organic enters into the extraction circuit in the No. 4 mixer and leaves the circuit from the No. 1 settler. As the aqueous solution advances, it is contacted with fresher organic which improves the efficiency of the extraction circuit. After the values have been removed from the aqueous (leaving No. 4 extraction settler) it is called the gallium sx raffinate. The organic leaving the No. 1 extractor is called the loaded organic since it now contains the zinc and gallium values.

A small amount of organic remains trapped as small droplets in the raffinate discharging from the No. 4 settler, so that solution goes into a raffinate scavenger tank (TK-501-16). The gallium sx raffinate is essentially leach solution that has had the copper, zinc and gallium removed from it. It still contains the germanium and becomes the feed solution for the germanium sx circuit.

The aqueous feed solution pH must be controlled within a narrow range for the extraction circuit to operate properly. As the aqueous solution advances through the extractors the pH of the solution may drop. If this happens, ammonia gas lines have been installed in the aqueous advance riser pipes from the settlers so that ammonia gas can be added if necessary. Caution is required whenever ammonia gas is added at any of these points since a localized precipitation can occur that might cause stable emulsions. Ammonia gas should be used only if instructed by the shift foreman.

SO₂ lines have been installed in the extractor circuit in case the aqueous solution begins to oxidize and iron loading on the organic becomes a problem. This usage should also be used only as directed by the shift foreman.

The extractors are equipped with internal organic recycle lines that bring organic from the settler unit back into the mixer so that the mixer sees more organic than is actually advancing between stages. This increases the organic to aqueous ratio in the mixer. Proper control of the organic to aqueous ratio in the mixer is important since it drastically affects the time that it takes for the organic and aqueous phases to separate when they overflow into the settler units. A discussion of the organic to aqueous ratio (O/A) is available in section 7.1.2 under the "extraction" subsection heading.

Stripping

The loaded organic (organic exiting from the No. 1 extractor that contains the zinc and gallium values) also carries small droplets of the aqueous solution from the extraction side that might contaminate the strip solution so the organic is washed with water acidified with sulfuric acid to a pH=1.8. The wash water, after contact, is pumped back into the extraction part of the circuit and the organic is now ready for the stripping operation.

Removal of the gallium and the zinc from the organic solution takes place in the strippers. A strong sulfuric acid (165 g H₂SO₄ per liter) solution will strip the gallium and zinc away from the organic, exactly opposite to the way in which the organic extracted the zinc and gallium from the sx feed solution.

The sulfuric acid strip solution (which is made up in the strip solution storage tank (TK-501-37) enters the strip circuit into the No. 4 strip mixer and flows countercurrently to the organic flow. The organic, which

enters at the No. 1 strip mixer, advances through the strip circuit until it leaves the No. 4 strip settler. The aqueous strip solution exits the strip circuit from the No. 1 stripper and contains the gallium and zinc values. It is called the preg, or loaded gallium strip solution and advances on to the gallium precipitation circuit.

The stripped organic either reports to the iron scrub or to the organic storage tank (TK-501-39) depending on how much iron is loaded on the organic as a contaminant. The organic storage tank is equipped with a manual valve located below the suction of the pump that is used to drain any aqueous that separates from the organic before it is pumped back to the extractors.

It may be necessary to add SO_2 gas to the strip circuit in order to keep the iron in the solutions reduced. Instructions to do so will be given through the shift foreman.

Organic Scrubbing

After all of the values have been removed from the organic through the strip circuit, the organic requires a scrub stage to restore its extraction capacity. Iron is strongly extracted onto the organic any time that it becomes oxidized and the natural action of pumping and mixing tends to oxidize some iron. It is necessary to remove some of that iron before recycling the organic back for the next extraction cycle to prevent it from building up on the organic.

Normally the iron contamination on the organic can be controlled by taking a portion of the stripped organic flow and scrubbing it and then recombining that portion with the unscrubbed part of the stream in the organic storage tank. The fraction of the organic stream that requires scrubbing will be established by the metallurgical department through the shift foreman.

The scrubbing section consists of a single mixer-settler unit. The organic is mixed with an aqueous solution containing 10% NaOH and 1% mannitol (a reducing agent). The scrub solution is made up in the iron scrub storage tank (TK-504). The iron scrub aqueous discharging from the scrub settler is pumped to the tailings neutralization circuit for disposal.

8.1.2 Circuit Operating Controls

Solution Preparation

The solution pH must be between 1.7 and 1.9 for proper operation of the extraction circuit. A pH higher than 1.9 may result in iron precipitation and emulsion formation while the gallium will not extract efficiently if the pH of the solution is below 1.7.

The solution must be clarified to no more than 5 NTU. The solution clarity is tested with a bench turbidity meter. A procedure for turbidity testing is included in Appendix A.

It is important to the overall operation of the mill to realize that the solution throughput through the gallium sx must be consistent with the processing rates of the copper and germanium sx circuits. Failure to process solution fast enough will result in the surge tanks filling up and forcing the rest of the plant to shut down. Processing solutions too fast may result in too much solution in the germanium sx circuit. It is also important not to empty the surge tanks completely since that would possibly cause a loss of feed to the circuit and could stir up settled solids on the tank bottom, either of which could create serious disruption of the operation.

The pressure gauge on the filter press is an important indicator of what is happening with the press. When the indicated pressure increases to a critical pressure (probably about 60 psi), it will be necessary to clean the press out. It will be important to have enough solution in the surge feed tank so that the sx can still operate while the filter press is out of service.

Extraction Circuit

It is very important in the extraction circuit to make sure that the proper organic flowrate is maintained for the given sx feedrate, zinc and gallium assays. Too little organic flow will result in high gallium assays since the organic can only pick up a given amount of zinc and gallium. Too much organic flow means that there is more chemical available to load zinc and gallium than there is metal to load. In this case, the chemicals in the organic will pick up other unwanted impurities. The proper organic to sx feed ratio is established by the metallurgical department through the shift foreman.

The sx feed and barren organic stream flows are equipped with flowmeters and control valves. It is expected that instrumentation on the sx feed and organic flow controllers will work together to change the organic flowrate to match any changes in the sx feed flowrate; however, the necessary ratio of organic flow to sx feed flow will fluctuate

depending on the zinc and gallium concentrations of the sx feed solution and the loading capacity of the organic on a given day. Samples of the organic in the circuit will be monitored periodically by the metallurgical department to determine its chemical content and its loading capacity. Each shift a sample of the loaded organic will be taken and analyzed to insure that it is picking up the expected amount of zinc and gallium.

The gallium sx raffinate (aqueous solution with the gallium removed), along with asx feed sample, is analyzed every three hours to insure that virtually all of the gallium is being extracted by the organic. An automatic sampler will take a 24 hr. composite sample to be used for overall metallurgical accounting purposes. Should a high raffinate (greater than .004 g Ga per liter) be obtained, an increase in the organic flowrate may be required to correct the situation. Other factors that might give a high raffinate include: a pH below 1.8 in the sx feed or the extractors, a depletion of DEHPA in the organic, excessive carryover of aqueous strip solution in the organic and exorbitant iron poisoning of the organic. Guidance as to corrective actions to be taken can be obtained through the shift foreman.

The rate that the organic and aqueous mixture separates back into separate liquids is an important parameter to monitor in the gallium sx extractors. If the liquids don't separate rapidly enough the mixed emulsion will eventually overflow the end of the settler and instead of clear organic and clear aqueous, one or both may look like the mixture in the mixer. When a sample of the mixture in a mixer is dipped from the tank, the time is measured until the aqueous and organic phases separate completely. The time for complete organic and aqueous phase separation is called the "break time". Each mixer in the circuit is monitored at least twice per shift and the break times recorded. Any drastic changes in mixer break time will inevitably result in circuit problems within a short period of time. Some of the circumstances that might result in a longer than normal break time include: loss of mixer organic to aqueous ratios, solids in the sx feed (or stirred up from the bottom of any settler) or from solutions that are colder than normal. Once any settler unit shows anything other than a clear organic and clear aqueous discharge, major circuit problems can occur.

Usually, it doesn't take long for a problem in one mixer settler unit to spread into others. Eventually, if the problems spread to the No. 1 extractor organic overflow or the No. 4 aqueous discharge, the circuit must be shut down and corrective actions taken.

The phase ratio (organic to aqueous ratio, or O/A) is usually measured at the same time as the break time by observing the relative volumes of the two liquids after they separate. The O/A ratio tells whether the recycle lines on the settlers is open or not. Improper O/A ratios will adversely affect the extraction, stripping and phase separation of the sx circuit. The expected O/A for the gallium extraction circuit is .75.

Normally, the continuous phase of a mixer is determined by the O/A in the mixer. Please see section 7.1.2 for a discussion of continuous phases and their significance. The O/A ratio of .75 means that the extraction circuit will operate in an aqueous continuous mode and that the aqueous solutions will have a greater number of droplets of organic entrained in them than if the continuous phase were organic. Drastic changes in the O/A may sometimes cause the continuous phase to "flip". This means that the continuous phase changes. Usually, phase separation decreases dramatically if the phases flip and that should be avoided.

Although the organic layer depths have no effect on the O/A ratios, it is necessary to have approximately 12 inches of organic in each settler. Less organic in the settler causes the organic to move faster through the settler and gives the organic less retention time.

Strip Section

The organic flowrate through the scrub and strip sections of the sx circuit is essentially the same as the flowrate of the barren organic, and whatever is fed into the extraction circuit must be processed through the organic wash and strip sections of the circuit.

The water wash, strip solution and iron scrub solution flowrates depend on the organic flowrate through them. These aqueous streams have rotometers that are used to control the flows. The operator will set these flows as directed through the shift foreman by the metallurgical department.

The operator will need to check the level of the water in the wash solution storage tank (TK-505) and prepare a new batch of pH 1.8 water as needed. This is done by filling the tank with water and adding acid until the pH is between 1.8 and 2.0.

Likewise, the strong acid strip solution tank (TK-507) level will be monitored and fresh strip solution made up

as required to feed the strippers. This will be done by setting the water rotometer and the acid rotometer to give the desired concentration (it will take approximately .9 liters of H_2SO_4 per 10 liters of water) and running them both until the tank is full. Although the ratio of water to acid necessary to obtain a 165 g/l solution can be estimated, it will still be necessary to run a free acid titration (procedure in Appendix A) to insure the proper strength of strip solution. Based on the titration, either additional water or acid may be called for to make the final concentration adjustment.

In the wash and strip stages of the circuit, the recycles are aqueous recycles rather than organic recycles like the extraction mixer-settlers have. This is because the advancing aqueous flow (either wash or strip solution) is so low compared to the organic flowrate. In order to maintain a reasonable separation (break time) in the mixers, it is necessary to increase the aqueous liquid volume (reduce the O/A ratio) that the mixer sees to a 2.0 for the strip and to a 3.0 for the organic wash stage.

Samples of the loaded organic, stripped organic, loaded strip solution and the iron scrub aqueous are taken once per shift and analyzed by the laboratory to assist the operator and other personnel control the operation and insure that the circuit is performing satisfactorily.

8.1.3 Sampling Requirements

The following table summarizes the routine daily sampling that is required for monitoring the gallium solvent extraction:

<u>Stream Sampled</u>	<u>Sample Point</u>	<u>Frequency</u>
gallium sx feed	feed tank	every 3 hrs.
gallium sx feed	feed tank	24 hr. composite
gallium sx raffinate	No. 4 ext. aq. disch.	every 3 hrs.
gallium sx raffinate	No. 4 ext. aq. disch.	24 hr. composite
gallium loaded organic	No. 2 ext. org. disch.	1 hr. before end of shift
gallium stripped organic	No. 4 stripper disch.	1 hr. before end of shift
gallium iron scrub. organic	org. disch. from iron scrub settler	1 hr. before end of shift

is further emphasized that any part of the sx circuit area is off limits to smoking and that any violation of the rule will result in employee dismissal (ie, employee de hiring, alternate career enhancement, firing, etc.).

Inevitably, in handling the organics in the circuit, walkways and boots will get coated with the organic and the potential for slipping increases. It is important to keep the area as clean as possible to help minimize the slipping hazards.

The organic in the circuit will eventually attack the rubber boots and as soon as a hole develops, the boots should be replaced. Don't wait until stepping into a pool of acid solution and getting a bootful of solution before determining that the boots should be replaced.

Walking or standing on the mixer or settler units should be avoided. The equipment is not designed to support much weight and a serious slipping hazard exists.

General safety precautions should be adhered to. There is a considerable amount of equipment in the gallium sx circuit and safety cannot be taken lightly.

9.0 Germanium Solvent Extraction

After the gallium has been removed from the leach solution, the germanium is removed from the gallium raffinate by solvent extraction (sx), and concentrated into a solution from which germanium can be selectively removed.

9.1 Process Description

Gallium sx raffinate solution is clarified and contacted four times with an organic (kerosene type) that contains 25 vol. % LIX 63 (see glossary) and 5 vol. % EHPA (see glossary) which is able to extract the germanium. The "loaded" organic is scrubbed with a strong acid solution to remove the iron, washed with water and the germanium is removed in two stages of stripping with a 200 g NaOH per liter strip solution. The caustic strip solution (preg or loaded strip solution) is then treated in the germanium precipitation and refining section to produce a final germanium dioxide product.

The germanium sx circuit is considerably more complex than the other solvent extraction circuits at the mill. It includes a solution preparation section, four stages (mixer-settlers) of extraction, four stages of strong acid iron scrubbing, one stage of water washing, two stages of stripping, one stage for copper scrubbing, a solvent acidulation stage and a MEHPA recovery stage.

9.1.1 Material Flow

A copy of the germanium solvent extraction circuit flow diagram is included as figure 9.1.

Solution Preparation

Gallium raffinate from the gallium raffinate scavenger tank (TK-501-16) is pumped to the acidulation reactor tank (TK-701-1) of the germanium sx circuit. The acidulation reactor tank is an agitated tank into which sulfuric acid is added. The amount of acid added is controlled by a flowmeter that is set based on the gallium raffinate feedrate into the tank.

The acidulation reactor tank is always full and it overflows into the surge tank (TK-701-2) that feeds a filter press (F-701-4).

The filter press is used to remove any suspended solids in the solution before solvent extraction. Solvent extraction circuits do not tolerate suspended solids very well. If essentially all solids are not removed from the solutions, they will mix with the organic and aqueous solutions in the mixers and will prevent the two liquids from separating in the settler units, usually collecting at the boundary (interface) between the organic and aqueous layers to form what is known as "grungies", "crud" or stable emulsions.

The filter press is built so that solutions must pass through a filter paper or cloth before leaving the press. Solids are trapped in the filter or cloth before leaving the press. Solids are trapped in the filter and removed later. As solids build up inside the filter, it becomes harder for the solutions to pass through the filter paper or cloth and the filter press will build a back pressure. The pressure gauge on the filter press will show a higher pressure until no more solution can pass through the filter and the filter press must be disassembled and cleaned.

For more difficult to filter materials it is possible to use a filter aid (easily filterable and porous material) to improve the filtration through either a precoat or a body feed method of addition. A discussion of those methods of filtering is given in section 1.1.5 of this manual.

After the solution is clarified through the filter press, it discharges into a storage tank (TK-701-5) which provides surge capacity. The pump from this tank pumps through a control valve that senses and regulates the flow into the

extraction circuit based either on the level of solution in the feed tank or the operator manual set point. A continuous uniform flow of sx feed solution is essential to the smooth operation of this circuit since any major fluctuations will start a surge through all mixer-settler stages in the circuit. Any changes in feed rate are made slowly.

Extraction

Germanium and some contaminants (iron and any copper left from the copper sx circuit) are transferred from the aqueous feed solution by mixing it with an organic (kerosene-type) containing LIX 63 and EHPA. Note that the EHPA used in the germanium sx circuit is different than the DEHPA in the gallium sx circuit. The aqueous feed solution and the organic are mixed together to transfer the metal values into the organic in the extraction part of the circuit.

Four extraction stages are used because the extraction of the germanium is not 100% complete in just one contact with the organic. The flows through the extraction are counter-current which means that the liquids advance in different directions. The sx feed aqueous enters into the No. 1 extractor and advances through Nos. 2 and 3 and exits the extraction circuit from No. 4. The organic enters into the extraction circuit in the No. 4 mixer and leaves the circuit from the No. 1 settler. Note that each extraction stage has a triple mixer (ie, 3 mixers in series). This gives the organic and aqueous mixture a longer time to react and transfer the germanium into the organic. A triple mixer is used instead of a single large mixer because it prevents solutions from short circuiting (not spending the required time in the mix tank). As the aqueous solution advances, it is contacted with fresher organic which improves the efficiency of the extraction circuit. After the values have been removed from the aqueous (leaving No. 4 extraction settler) it is called the germanium sx raffinate. The organic leaving the No. 1 extractor is called the loaded organic since it now contains the germanium.

A small amount of organic remains trapped as small droplets in the raffinate discharging from the No. 4 settler, so that solution goes into a solvent scavenger tank (S-701-51). The germanium sx raffinate is essentially leach solution that has had the copper, zinc, gallium and germanium removed from it. It is now a waste product and goes to the raffinate neutralization circuit for treatment prior to disposal in the tailings ponds.

The aqueous feed solution into the germanium sx circuit must be acidified until it contains at least 80 g H_2SO_4 per liter of solution for the extraction circuit to operate properly.

The extractors are equipped with internal organic recycle lines that bring organic from the settler unit back into the mixer so that the mixer sees more organic than is actually advancing between stages. This increases the organic to aqueous ratio in the mixer. The design O/A for the germanium sx extractors is 1.2. Proper control of the organic to aqueous ratio in the mixer is important since it drastically affects the time that it takes for the organic and aqueous phases to separate when they overflow into the settler units. A discussion of the organic to aqueous ratio (O/A) is available in section 7.1.2.

Loaded Organic Scrubbing and Stripping

Small, but significant, quantities of iron, arsenic, zinc, nickel, copper and molybdenum (not extracted in the prior sx circuits) are loaded onto the organic along with the germanium.

A scrub circuit consisting of four stages is used to remove the iron, arsenic and zinc impurities by mixing the organic in conventional mixer-settlers with a strong sulfuric acid (200 g H_2SO_4 per liter) scrub solution. The scrub solution is prepared in the scrub storage tank (TK-701-48) by mixing fresh water, water from the water wash mixer settler and sulfuric acid.

The flow through the scrub circuit is counter-current to achieve the maximum scrubbing efficiency. That means that the loaded organic enters into the No. 1 Ge acid scrub mixer (701-19) and advances through until it exits the No. 4 Ge acid scrub settler (701-26). The acid scrub solution advances from the opposite direction, entering the No. 4 Ge acid scrub mixer (701-25) and exiting the No. 1 Ge acid scrub settler (701-20). The cleaned organic still contains the germanium and is washed in the Ge water wash mixer-settler to remove any acid carryover before reporting to the caustic strip circuit. The scrub solution, containing impurities (mostly iron) after contacting the organic, is sent to the Ge solvent acidulation mixer where the acid content of the stream is used to condition the stripped organic before the scrub solution is recycled back to the leach circuit.

Once the organic has been acid scrubbed and water washed, it advances to the No. 1 Ge strip mixer (701-29). Germanium is removed from the organic by a strong caustic

(200-300 g NaOH per liter) solution. Note that the strip uses a strong caustic (or base) for removing the germanium while the rest of the circuit is quite acidic. Special precautions should be taken to insure that the caustic solutions do not mix with the acidic solutions. Two stages of counter-current contact with the caustic strip solution is required to remove the germanium from the organic. Thus, like other counter-current circuits, the organic enters the No. 1 Ge strip mixer (701-29) and exits the No. 2 settler (701-32), while the caustic strip solution feeds into the No. 2 mixer (701-31) and exits from the No. 1 settler (701-30) as the Ge loaded strip solution. The Ge loaded strip solution is then pumped to the Ge recovery tank (TK-901-1) for final processing and packaging.

Caustic strip solution is prepared in the strip storage tank (TK-701-46) by setting the water and caustic solution flows to the proper flowrate ratio (3.3 liters of 50% caustic to 10 liters of water) and filling the tank. After the tank is filled, a caustic titration is performed to verify the proper caustic strength. The procedure for free caustic titrations is included in Appendix A. Either caustic or water may be added as required to make any final adjustment in the caustic concentration.

Other Treatment Steps

A. Copper treatment - Although most of the elements that loaded onto the organic during extraction are removed by either the strong acid scrub (iron, zinc, arsenic) or in the germanium strip with the strong caustic solution (Ge), a possible buildup of copper and nickel on the organic exists. If these elements are allowed to build up on the organic too long, they might poison (reduce the loading capacity) the organic. To prevent this from happening a copper treatment stage (single mixer-settler) is present in the circuit to treat a bleed stream (designed to be 1/3 of the total organic flow). The organic bleed stream is mixed with a solution of ammonia, sulfuric acid and water. The reaction of sulfuric acid with ammonia gas makes ammonium sulfate. The ammonium sulfate is prepared in a batch operation in the Cu treatment solution tank (TK-701-41) by adding .1 liters of sulfuric acid per liter of water to the tank and then neutralizing the acid solution to a pH=6.0 with ammonia gas.

The copper enriched scrub solution is then pumped over to the copper sx feed reactor (TK-301-1).

B. Organic acidulation - The organic from the caustic strip circuit is split with part of the stream going to the copper treatment mixer-settler and the remaining flow

going into the Ge solvent acidulation mixer-settler (701-33 and 701-34). After the split stream of organic is treated for copper removal, it also reports to the solvent acidulation mixer-settler. The purpose for the solvent acidulation stage is to recondition the organic before it recycles back to the extraction part of the circuit. It is very difficult to mix an organic stream that has been contacted with a highly caustic solution directly with highly acidic streams such as that found in the extraction circuit. Usually, solids will precipitate resulting in stable emulsions, and the organic will do very little extracting until it becomes conditioned to the acid solution.

The aqueous used to condition the organic is the same acidic (200 g H_2SO_4 per liter) solution that was used to scrub the iron from the organic in the Ge acid scrub section.

After acidulation, the stripped and conditioned organic is pumped to the organic storage tank (TK-701-18). Organic is pumped from this tank back to the extraction circuit. This tank has a drain valve near the bottom of the tank so that any aqueous that separates out in the tank can be manually drained out rather than being pumped back into the extractors with the organic.

C. MEHPA Recovery Circuit - One of the unique features of the germanium sx circuit is that some of the critical chemical used in extracting the germanium dissolves in the caustic strip solution. The MEHPA (part of the EHPPA reagent) dissolves in the caustic strip solution and follows the germanium to the precipitation and refining circuit. There, the germanium is precipitated (converted back into a solid) after acidifying with sulfuric acid. The germanium is then filtered from the solution. The filtrate (solution) still contains the MEHPA and is brought back to the germanium sx circuit where it is acidified to 80 g H_2SO_4 per liter. The MEHPA then separates from the aqueous solution. A small stream of organic from the organic storage tank is mixed with the acidified MEHPA stream and the MEHPA redissolves into the organic. The organic is then drawn off the settler and returns to the organic storage tank with the MEHPA that it has recovered. As long as the solutions that the organic contacts are acidic, the MEHPA stays dissolved in the organic.

9.1.2 Circuit Operating Controls

Solution Preparation

The acidity of the germanium sx feed solution must be at least 80 g H_2SO_4 per liter. A lower acid content will result in unacceptable germanium extraction and slower separation rates while a higher acid content results in wasted acid and higher reagent costs.

The solution must be clarified to no more than 5 NTU. The solution clarity is tested with a bench turbidity meter. A procedure for turbidity testing is included in Appendix A.

It is important to the overall operation of the mill to realize that the solution throughput through the germanium sx must be consistent with the processing rates of the gallium sx circuit. Failure to process solution fast enough will result in the surge tanks filling up and forcing the rest of the plant to shut down. It is also important not to empty the surge tanks completely since that would possibly cause a loss of feed to the circuit and could stir up settled solids on the tank bottom, either of which could create serious disruption of the operation.

The pressure gauge on the filter press is an important indicator of what is happening with the press. When the indicated pressure increases to a critical pressure (yet to be determined), it will be necessary to clean the press out. It will be important to have enough solution in the surge feed tank so that the sx can still operate while the filter press is out of service.

Extraction Circuit

It is very important in the extraction circuit to make sure that the proper organic flowrate is maintained for the given sx feedrate and germanium assay. Too little organic flow will result in high germanium raffinate assays since the organic can only pick up a given amount of germanium. Too much organic flow means that there is more chemical available to load germanium than there is metal to load. In this case, the chemicals in the organic will pick up other unwanted impurities such as iron, zinc, etc. The proper organic to sx feed ratio is established by the metallurgical department through the shift foreman. The sx feed and barren organic stream flows are equipped with flowmeters and control valves. It is expected that instrumentation on the sx feed and organic flow controllers will work together to change the organic flowrate to match any changes in the sx feed flowrate; however, the necessary

ratio of organic flow to sx feed flow will fluctuate depending on the zinc and gallium concentrations of the sx feed solution and the loading capacity of the organic on a given day. Samples of the organic in the circuit will be monitored periodically by the metallurgical department to determine its chemical content and its loading capacity. Each shift a sample of the loaded organic will be taken and analyzed to insure that it is picking up the expected amount of germanium.

The germanium sx raffinate, along with the germanium sx feed, is analyzed every three hours to insure that virtually all of the germanium is being extracted by the organic. An automatic sampler will take a 24 hr. composite sample to be used for overall metallurgical accounting purposes. Should a high raffinate (greater than .003 g Ge per liter) be obtained, an increase in the organic flowrate may be required to correct the situation. Other factors that might give a high raffinate include: not enough acid in the sx feed, a depletion of chemicals in the organic, and exorbitant iron, copper or zinc poisoning of the organic. Guidance as to corrective actions to be taken can be obtained through the shift foreman.

The rate that the organic and aqueous mixture separates back into separate liquids is an important parameter to monitor in the germanium sx extractors. If the liquids don't separate rapidly enough the mixed emulsion will eventually overflow the end of the settler and instead of clear organic and clear aqueous, one or both may look like the mixture in the mixer. When a sample of the mixture in a mixer is dipped from the tank, the time is measured until the aqueous and organic phases separate completely. The time for complete organic and aqueous phase separation is called the "break time". Each mixer in the circuit is monitored at least twice per shift and the break times recorded. Any drastic changes in mixer break time will inevitably result in circuit problems within a short period of time. Some of the circumstances that might result in a longer than normal break time include: loss of mixer organic to aqueous ratios, solids in the sx feed (or stirred up from the bottom of any settler), too little acid in the feed solution or from solutions that are colder than normal. Once any settler unit shows anything other than a clear organic and clear aqueous discharge, major circuit problems can occur.

Usually, it doesn't take long for a problem in one mixer settler unit to spread into others. Long before the problems spread to the No. 1 extractor organic overflow or the No. 4 aqueous discharge, the circuit must be shut down and corrective actions taken.

The phase ratio (organic to aqueous ration, or O/A) is usually measured at the same time as the break time by observing the relative volumes of the two liquids after they separate. The O/A ratio tells whether the recycle lines on the settlers is open or not. Improper O/A ratios will adversely affect the extraction, stripping and phase separation of the sx circuit. The expected O/A for the germanium extraction circuit is 1.2.

Normally, the continuous phase of a mixer is determined by the O/A in the mixer. Please see section 7.1.2 for a discussion of continuous phases and their significance. The O/A ratio of 1.2 means that the extraction circuit will operate in an organic continuous mode and that the organic will have a greater number of droplets of aqueous entrained in it than if the continuous phase were the aqueous. Drastic changes in the O/A may sometimes cause the continuous phase to "flip". This means that the continuous phase changes. Usually, phase separation decreases dramatically if the phases flip and that should be avoided.

Although the organic layer depths have no effect on the O/A ratios, it is necessary to have approximately 12 inches of organic in each settler. Less organic in the settler causes the organic to move faster through the cell and gives the organic less retention time.

Strip Section

The organic flowrate through the germanium acid scrub and strip sections of the sx circuit is essentially the same as the flowrate of the barren organic, and whatever is fed into the extraction circuit must be processed through the Ge acid scrub, wash and strip sections of the circuit.

The Ge acid scrub aqueous, water wash, caustic strip solution and copper treatment solution flowrates depends on the organic flowrate through that part of the circuit. These aqueous streams have rotometers that are used to control the flows. The operator will set these flows as directed through the shift foreman by the metallurgical department.

The operator will need to check the level of the solution in the Ge scrub storage tank (TKH-901A) and prepare a new batch of 200 g H_2SO_4 per liter solution as needed. This is done by filling the tank with water and adding acid simultaneously at the appropriate rate (.11 liter of acid to each liter of water) until the tank is full. The free acid of the solution is checked and final adjustments made by either adding water or more acid.

Likewise, the caustic strip solution tank (TKH-1016) level will be monitored and fresh strip solution made up as required to feed the strippers. This will be done by setting the water rotometer and the caustic rotometer to give the desired concentration (3.3 liters of 50 % NaOH to each 10 liters of water) and running them both until the tank is full. Although the ratio of water to 50 % caustic necessary to obtain a 200 g/l solution can be estimated, it will still be necessary to run a caustic titration (procedure in Appendix A) to insure the proper strength of strip solution. Based on the titration, either additional water or caustic may be called for to make the final concentration adjustment.

In the scrub and strip stages of the circuit, the recycles are aqueous recycles rather than organic recycles like the extraction mixer-settlers have. This is because the advancing aqueous flow (scrub, wash or strip solution) is so low compared to the organic flowrate. In order to maintain a reasonable separation (break time) in the mixers, it is necessary to increase the aqueous liquid volume (reduce the O/A ratio) that the mixer sees O/A ratios of 2.0 for the scrub, .8 for the strip and 2.0 for the organic acidulation.

Samples of the loaded organic, scrubbed organic, stripped organic, loaded strip solution, copper treated organic and the iron scrub aqueous are taken once per shift and analyzed by the laboratory to assist the operator and other personnel controlling the operation and insure that the circuit is performing satisfactorily. Samples of the sx feed and raffinate are taken and analyzed every three hours.

9.1.3 Sampling Requirements

The following table summarizes the routine daily sampling that is required for monitoring the germanium solvent extraction:

<u>Stream Sampled</u>	<u>Sample Point</u>	<u>Frequency</u>
Ge sx feed	feed tank	every 3 hrs.
Ge sx feed	feed tank	24 hr. composite
Ge sx raffinate	No. 4 ext. aq. disch.	every 3 hrs.
Ge sx raffinate	No. 4 ext. aq. disch.	24 hr. composite
Ge loaded organic	No. 2 ext. org. disch.	1 hr. before end of shift

Ge stripped org.	No. 4 stripper disch.	1 hr. before end of shift
Ge iron scrubbed organic	Org. disch. from iron scrub settler	1 hr. before end of shift
Ge preg strip	No. 1 strip disch.	1 hr. before end of shift
Ge iron scrub aq.	No. 1 iron scrub aq. advance	1 hr. before end of shift

9.2 Operator Duties and Responsibilities

Operators are expected to comply with all general personnel procedures pertaining to attendance, discipline, and general mill safety, etc. The operator reports directly to the shift foreman. Specific duties and responsibilities related to the operation of the germanium sx include, but may not be limited to:

- 1) manually checking the free acid on the reactor tank at least every two hours;
- 2) checking the organic to aqueous ratios in the mixers of all mixer settlers at least twice per shift. As part of this measurement the operator should be alerted to any mixers that are indicating any longer than normal break times;
- 3) measuring the organic depths in each of the settler units at least twice per shift. The accumulation of solids of unseparated emulsion at the boundary between the clear aqueous and clear organic is also recorded;
- 4) checking all tank levels at least every two hours (more frequently if there is no instrumentation on the tank to alert the operator);
- 5) titrating the free acid content of the fresh scrub solution in the makeup tank after making up a new batch; likewise, titrating the free caustic in the fresh strip solution makeup tank;
- 6) checking the pressure on the filter press every two hours;
- 7) bleeding the collected aqueous from the organic storage tank at least once per shift;

1.2 Glossary of Terms

Acid - A typically water soluble compound that is capable of reacting with a base to form a salt. Acids form hydrogen ions in water solutions. All acids have a pH below 7.0. Sulfuric and hydrochloric acids are the commonly used acids at the mill.

Agitator - A mixing machine like a propeller on a shaft that is put in the liquid or pulp to stir it. Leach tanks and sx mixers have agitators in them.

Alkali - The oxide or hydroxide of some metals, especially when dissolved in water, that react with an acid to make neutral compounds called salts. Lime is an alkali. All alkalis have a pH above 7.0.

Amp (Ampere) - A unit of electric current.

Antidote - A medicine taken to counteract the effects of a poison.

Aqueous - Means water or mostly water. Most process streams are aqueous streams because they are water with other substances dissolved in it. In solvent extraction the term is used frequently to easily distinguish between organic (oil) or water based streams. Examples of aqueous streams include: leach solutions, raffinates, strip solutions, scrub solutions and electrolytes.

Assay - A measure of how much metal is in a product or process stream. It may be expressed as percent (%), grams per liter (gpl) or in ounces per ton (OPT).

Base - A synonym for an alkali. Produces hydroxyl ions in a solution.

Ball Charge - Refers to the volume inside a ball mill that is occupied by the grinding balls.

Ball Mill - A size reduction process where steel balls are tumbled in a rotating cylinder with rock particles that are to be ground finer.

Blinds - In process terminology, blinds means to plug off. Typically, a filter cloth "blinds" off when it becomes plugged with solids and ceases to allow solutions through.

Body Feed - This term refers to a filtering procedure

for slimy or difficult to filter solids. Filter aid (Dicalite, diatomaceous earth, etc.) is fed into the solution to be filtered so that the difficult to filter solids in the solution get mixed with the easily filterable filter aid.

Bus - A conductor which serves as a common connection for the corresponding conductors of 2 or more circuits.

Bypass System - A group of equipment that enables process flows to miss an item of equipment and continue to the next step.

Centerwell - In a thickener it is the cylindrical shell structure that is suspended in the middle of the thickener. One open end is above the solution level while the other is below. Slurry is introduced into the thickener through the open end on top and enters the thickener through the submerged open end. This prevents short circuiting of the slurry flow to the overflows, improves solution clarity and solids settling.

Chemical Formulas - Abbreviations for chemicals. The most common used in the plant are as follows:

<u>Chemical</u>	<u>Formula</u>
Sulfuric Acid	H ₂ SO ₄
Sulphur Dioxide	SO ₂
Ammonia (Anhydrous Ammonia)	NH ₃
Caustic Soda (Sodium Hydroxide)	NaOH
Hydrochloric Acid	HCl
Sulfur	S
Oxygen	O
Copper	Cu
Gallium	Ga
Germanium	Ge
Iron	Fe
Arsenic	As
Methyl Isobutyl Ketone	MIBK
Di 2 ethylhexyl phosphoric acid	DEHPA
Tributyl Phosphate	TBP

Clarified - Means to have the solids removed. A clarified solution is clear because the solids that made it cloudy have been removed.

Clarifier - A filter or thickener designed to remove small amounts of fine solids to make a crystal clear solution.

Classification - A method of separating different size particles such as a vibrating screen.

Concentrate - A product from a separation process that is richer in metal value than the feed.

Diatomaceous Earth - A naturally occurring earth used in filter media.

Differential Pressure Switch - A pressure switch that monitors pressure at two locations, tripping if the two pressures are not the same.

Disconnect - An electric power switch or device with which the conductors of a circuit can be disconnected from their source of supply. Normally, the disconnect can be operated when the circuit is not under load.

Dynamic Load - A moving load such as the force of the wind on the side of a building, the rotation of a mill or the movement of a vehicle over the ground.

Emulsion - A thorough mixture of organic (oil) and aqueous (water process streams). Emulsions are made in the sx mixers... A stable emulsion is one that doesn't readily separate back into organic and aqueous phases within a couple of minutes.

Extract - Means to remove something. In solvent extraction the organic removes (extracts) the metal values from the leach solution.

False Bottom - In an sx mixer the pipes feeding into the base of the mix tank enter a chamber separated from the main part of the mixer by a fiberglass plate with a hole in the center. The action of the mixer vanes create a suction on the hole in the center of this plate and acts as a pump, pulling the solutions from the false bottom chamber into the main mix chamber. It is called a false bottom because you can't tell it is there by looking at the outside of the mixer.

Filter - A device or piece of equipment for separating solids from liquids or slurries. The essential feature is a filter cloth through which filtrate (the fluid phase of the feed) is either forced under the pressure or drawn under vacuum. The solids are retained by the cloth on the feed side.

Filter Aid - An easily filterable material such as Dicalite or diatomaceous earth added to a filtering process to speed up filtration, prevent cloth blinding or improve clarity.

Filter Cloth - Usually a synthetic woven material used to trap solids when a solution is passed through it.

Filter Paper - A natural or synthetic material pressed into shape and is used to trap solids when a solution is passing through it.

Filter Cake - The solids that accumulate on the filter cloth as moisture is removed through the cloth.

Filtrate - The clear liquid that passes through the filter cloth.

Flocculent - A chemical which causes fine particles to stick together in clusters (flocs). The larger agglomerations behave in a number of processes as large single particles (but with a lower density than the original solids of the same volume) which can be helpful in both thickening and filtration.

Gram - The metric measurement of weight. It takes 453.6 grams to equal one pound. The abbreviation is g.

gpl - Measure of the concentration of a dissolved substance. It stands for grams per liter.

Grinding - Breaking rocks into very small pieces by subjecting them to stresses. Usually carried out wet in ball mills. These mills are rotating cylinders filled with grinding balls that collide with the particles and break them.

Grounded - Connected to the earth.

Head - The feed to a plant or process.

Hz (Hertz) - Cycles per second. A measure of electrical frequency. 60 Hz is common.

Launder - An open, sloping ditch-like fabricated structure for conveying liquids or flowable pulps. May be made from almost any material such as steel, wood, concrete, etc.

Leach - A process where a liquid or solution reacts with a solid and causes it to dissolve.

Leach Tank - A tank designed to hold solutions and the solids they are leaching. Usually fitted with a mixing mechanism or agitator.

Lime - Calcium oxide, calcium carbonate or calcium hydroxide. An alkali made from limestone.

Limestone - A naturally occurring rock of calcium carbonate. It is a base and gives off carbon dioxide gas (foams) when it reacts with acid.

Liquid Ion Exchange - Refers to a process using two liquids (usually an oil based and a water based) that will not dissolve into each other, that when mixed together will transfer a dissolved substance in one liquid into the other. Solvent extraction is the prime example of liquid ion exchange.

Load - In solvent extraction, refers to the attaching of metal ions onto the organic. An organic with a relatively high concentration of a specific metal dissolved into it is called a loaded organic.

Load Cell - An electronic device which measures weight by means of a strain gauge. It replaces the old balance beam principle.

Loaded Electrolyte - In copper sx, refers to the electrolyte (aqueous solution from the electrowinning circuit) that is enriched in copper values.

Loaded Organic - An organic with a relatively high concentration of a specific metal dissolved into it.

Marcy Density Scale - A simple machine for measuring pulp density. It consists of a 1 liter bucket (can) and a spring balance. The machine is periodically checked by using fresh water and the needle adjusted to 0% solids which coincides with a specific gravity of 1.0 on the outer scale. The density of pulp is measured by then filling the bucket with pulp, and either reading the specific gravity on the outer scale, or more usefully, directly reading the % solids by weight by reading the appropriate specific gravity scale.

Mesh - A system of size measurement used for screens. The mesh number is the number of screen openings per inch on a standard square opening woven screen.

Micron - One thousandth of a millimeter or one millionth of a meter. It is used for measuring very small distances such as openings in screens and the size of fine particles.

Mineral - A natural occurring solid with a definite chemical composition.

Mixer - In solvent extraction, refers to the agitated tank where the organic and aqueous get mixed together so ion exchange can take place. In other applications it refers to the device that stirs liquids or slurries.

MCC (Motor Control Center) - The MCC is a rack containing motor starters for the various low voltage motors in the plant.

NEMA - An American Standard namely, the National Electrical Manufacturer's Association.

Ore - Rock which contains mineral values that can be recovered at a profit.

Orifice Plate - A metallic disk with a round hole in the middle inserted in a pipe. It causes pressure differentials that can be related to flow. The size of the hole depends on pipe size, flow and pressure.

Overflow Solution - The clear solution that overflows into the overflow launder of the thickener.

Percent - A fraction of a total. 1 part of 100 is 1 percent.

Percent Solids - That fraction of a slurry which is rock, the balance normally being water or a water solution. It can be measured by a Marcy Density Scale.

pH - A measure of the amount of acid or base. A pH between 0 and 7 is acidic while a pH between 7 and 14 is considered basic. PH is measurable by electronic instruments. Solutions that contain more acid or base than can be measured by the instruments are determined by titration procedures.

Pinion Bearing - The bearings that hold the mill drive shaft (pinion) in position against the ball mill.

Plates - The middle sections of a filter press that either distribute new solution into the filter or collect the solution after it has passed through the filter cloth.

P.P.M. - Parts per million. A way of expressing analytical results for small concentrations.

Precipitation - The removal of dissolved substances from a solution by the addition of a reagent of chemical to produce a solid and a "barren" solution. Turns the dissolved substance back into a solid.

Precoat - In filter press operation sometimes it is necessary to feed filter aid into the press before the solution to be filtered in order to build up a filter cake of filter aid. This generally results in better solids removal from the solution.

Pregnant Strip - Refers to the strip solution after it has removed the metal values from the organic. It is generally a relatively pure and concentrated solution stream.

Process Solution - Any of the plant solutions or mixtures of them. It is used to distinguish process fluids from fresh water.

Pulp - Another name for slurry.

Pulp Density - The ratio of solids and liquid in a pulp. It can be expressed as either % solids or specific gravity.

- a) the wt. of solids divided by the wt. of pulp multiplied by 100 gives the percent solids.
- b) the wt. of 1 liter of pulp divided by the wt. of 1 liter of water gives the pulp specific gravity.

Pumper Mixer - Solvent extraction mixer units act as pumps due to the shape of the agitator and the false bottom in the mix tank. They are also called pumper mixers.

Quick Lime - CaO made by reacting lime with water.

Raffinate - The aqueous leach solution after a metal value has been removed by solvent extraction.

Rake - A rotating mechanism inside a thickener that scrapes mud toward the center of the thickener (cone) so that it can be removed.

Reagents - Organic or inorganic chemicals that are used in the mill operation.

Regeneration - When an organic becomes contaminated with a substance that is not normally removed by the process it is treated with additional chemicals to clean it for reuse.

Repulp - Mix liquid into pulp or solids (filter cakes) that have previously had the liquid removed. For example, the filter cake from the belt filter will be repulped with water.

Sampler - Something that takes a small portion of the process stream as representative of the full stream.

Screen - A device with openings used to separate particles according to size.

Scrub - The process of cleaning an organic without removing any of the metal that it is designed to extract.

Seal Pot - A tank (or part of a tank) that seals a vacuum or gas from atmosphere by using the liquid reservoir.

Seal Water - Water that is pumped into the small space between a rotating shaft and a fixed case to prevent leakage of corrosive or abrasive material from within the equipment damaging the shaft or casing.

Settler - The large flat tanks that are used in the solvent extraction to allow time for the organic and aqueous mixture (emulsion) to separate. See attached sketch.

Slaking - The act of mixing lime with water to make quick lime.

Slurry - A mixture of solids and liquids such as ore particles in process solution or water.

Solvent - The organic (with chemicals dissolved in it) used to extract metal values from leach solutions.

Specific Gravity - The ratio between the weight of a substance or mineral and the weight of an equal volume of water. Thus, a mineral with a specific gravity of two, weighs twice as much as an equal volume of water.

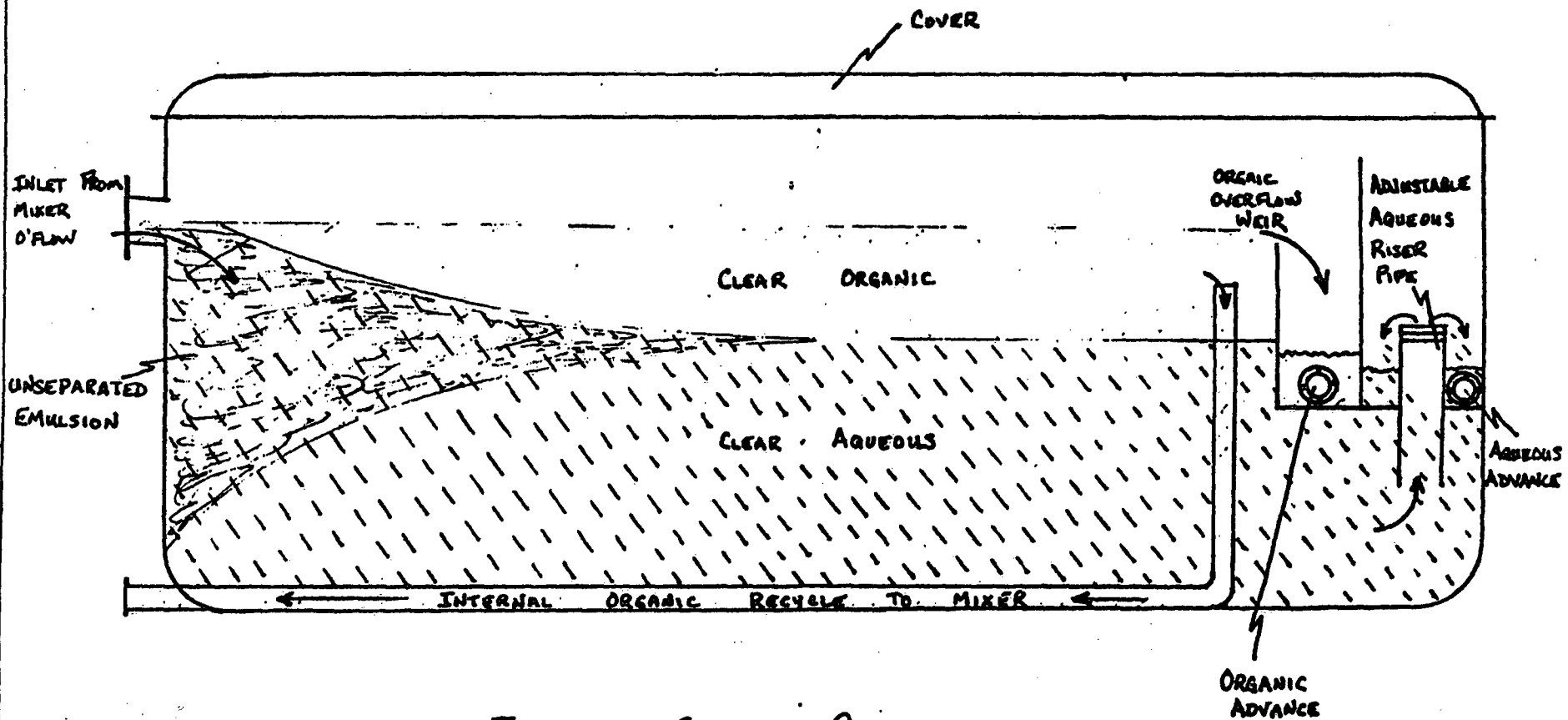
Sprag Rod - A steel bar that is pushed into a chute or feeder to hold up rock and effectively block off the opening.

Stage - In solvent extraction a stage refers to the combination of a mixer and a settler unit.

Static Load - A stationary load such as the cladding on buildings or the weight of the control room.

Strip - In solvent extraction it is the process of removing the desired metal values from the loaded organic.

Strip Solution - The solution used to remove the extracted values from the loaded organic in solvent extraction.



TYPICAL SETTLER CROSSSECTION

Solvent Extraction (SX) - Refers to the use of a solvent (organic with chemicals dissolved in it) to extract a metal value and transfer it to a more concentrated and purer aqueous solution. Involves loading and stripping the values from the organic.

Tailings - The waste produced from mineral processing operations, usually a slurry.

TEFC - Type of electrical motor - totally enclosed, fan cooled.

Thermostat - A temperature sensitive switch.

Thickener - A piece of equipment for separating liquid and solids. It consists of a tank into which pulp is fed and the solids allowed to settle. The essentially clear liquid (overflow) overflows into a collecting launder around the tank rim. There is a slowly rotating mechanism mounted in the center which scrapes the settled solids towards the center. The solids, as a high density pulp, are withdrawn from a cone located in the center of the tank base (underflow).

3-Phase - Electrical power system consisting of 3 line wires (and neutral) forming a symmetrical alternating current system.

Titration - A chemical analysis method. Small quantities of a standard solution are successively added to the solution being tested from a burette (a calibrated tube with a tap). A chemical reaction takes place and when a slight excess of the standard solution remains this is shown by a precipitate or color change (or some other visible sign such as pH on a pH meter).

Trunnion Bearing - The main bearings on the ends of the ball mill that carry the weight of the mill and the load in the mill.

Underflow - The thickened slurry that is pumped from the cone of the thickener.

Upcomer - A pipe that extends to near the bottom of a tank that slurry must pass through to exit the tank. The weight of the slurry in the tank forces the slurry near the bottom of the tank to enter the pipe. The pipe ends up discharging to the top of the next tank. This arrangement is commonly used to prevent short circuiting of solutions or slurries across the top of tanks.

Waste - Rock that contains no valuable minerals of sufficient value to be mined and processed at a profit.

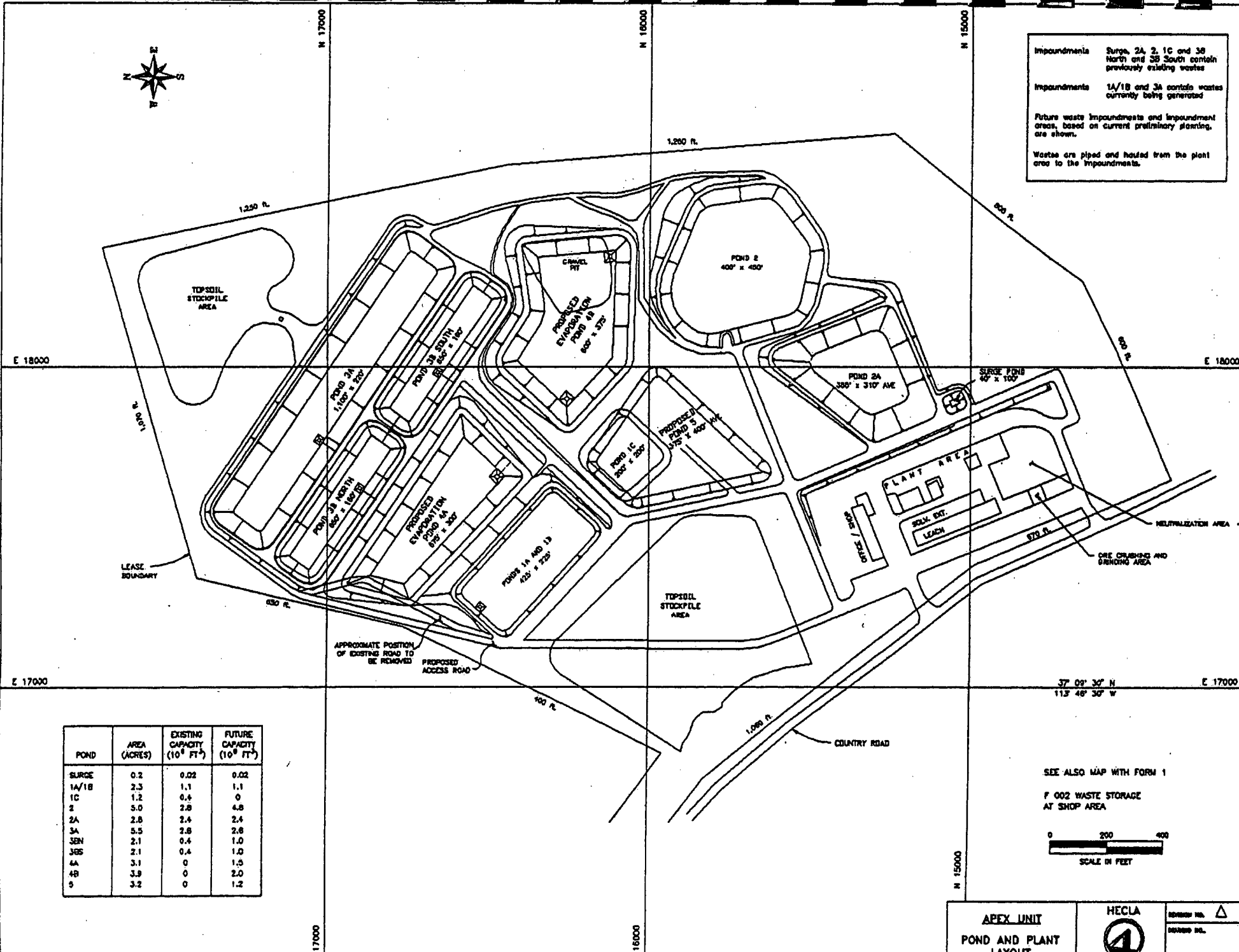


Impoundments Surge, 2A, 2, 1C and 3B North and 3B South contain previously existing wastes

Impoundments 1A/1B and 3A contain wastes currently being generated

Future waste impoundments and impoundment areas, based on current preliminary planning, are shown.

Wastes are piped and hauled from the plant area to the impoundments.



POND	AREA (ACRES)	EXISTING CAPACITY (10 ⁶ FT ³)	FUTURE CAPACITY (10 ⁶ FT ³)
SURGE	0.2	0.02	0.02
1A/1B	2.3	1.1	1.1
1C	1.2	0.4	0
2	5.0	2.8	4.8
2A	2.8	2.4	2.4
3A	5.5	2.8	2.8
3B	2.1	0.4	1.0
3B	2.1	0.4	1.0
4A	3.1	0	1.5
4B	3.9	0	2.0
5	3.2	0	1.2

SEE ALSO MAP WITH FORM 1

F 002 WASTE STORAGE AT SHOP AREA

0 200 400

SCALE IN FEET